OPERATIVE TECHNIC

IN

GENERAL SURGERY

Edited by

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Introduction by

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THE BLOOD VESSELS

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ACUTE VASCULAR INJURIES

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Acute or fresh injuries of major arteries, because they literally threaten both life and limb, have always constituted a serious problem in the surgical management of traumatic conditions. Despite the constant and tireless efforts of numerous investigators and the extensive experience provided by both World Wars, a completely satisfactory solution to this problem has yet to be evolved. Obviously, and this has long been recognized, ideal therapy has as its objective preservation or restitution of vascular function. Unfortunately, as pointed out in a previous consideration of this subject,[5] this desideratum can be attained in only a limited number of cases, for certain definite reasons. Essentially, these reasons may be divided into two categories: (1) those in which the factors are of such vital significance that they seal the fate of the part regardless of any form of therapy; and (2) those which jeopardize the effects of ideal therapy or preclude its institution. These factors are; time-lag, practical technical considerations, the presence of associated injuries, the site of injury, the type of arterial lesion, and the possible occurrence of infection.

The significance of the time-lag, *i.e.*, the time elapsing between wounding and institution of therapy, is obvious. Once this period exceeds the generally accepted limit of 6 to 8 hours, it is doubtful that reparative surgical therapy can influence the end result. The factor of associated injuries, whether they are local or remote, is also of considerable importance. Local wounds, depending upon their extent, may further impair or even completely destroy the regional circulation. More remote wounds may require attention far more urgently, as a lifesaving matter, than does the vascular wound.

Perhaps the most important factors determining end results are the site and type of the arterial lesion. Wounds of certain vessels, such as the popliteal artery, are far more serious than wounds of other vessels, such as the brachial artery. Wounds above the profunda branch in both the femoral and brachial arteries are more likely to be followed by ischemic gangrene than wounds of these vessels below this branch. Accordingly, certain vessels have come to be regarded as critical and others as noncritical, and restora-

tive surgical procedures obviously assume greater importance in the former category of vessels than in the latter. The type of injury (laceration of the vessel, partial or complete severance, contusion and thrombosis, acute spasm, or false aneurysm) also influences the outcome. A small, cleanly incised longitudinal wound, or even an incised transverse wound, may be repaired with greater chances of success than a lacerated wound in which there is much loss of substance.

In vascular injuries, therefore, the circumstances and character of the injury often determine the therapeutic procedure and consequently predetermine the end result. Under certain conditions the only procedure applicable is ligation; it must be done for the basic purpose of controlling hemorrhage. Under other conditions some type of reparative procedure may be employed; since this constitutes ideal therapy, every effort should be made to apply it.

Supplemental Therapeutic Measures. All the established principles of good wound surgery, such as proper resuscitation of the patient and thorough débridement, are essential to the successful management of acute vascular injuries. These principles are discussed elsewhere and require no further elaboration here. There are, however, certain supplemental therapeutic measures that deserve consideration, including blood transfusion, sympathetic block or sympathectomy, anticoagulant therapy, and posture.

The extent of blood loss in acute vascular injuries is often considerable. As a consequence of the reduction in the volume of the circulating blood, the amount of blood flow through the peripheral arteries is also reduced, and the circulation of the part distal to the vascular injury is even further impaired. For these reasons, prompt restoration of the circulating blood volume and of the hemoglobin concentration assumes particular importance.

Vasospasm is a natural response to those forms of trauma which directly or indirectly affect vascular structures.[4] Its extent and degree vary considerably. It may range from localized constriction, with consequent minimal ischemia, to a more extensive and generalized involvement, especially of the collateral circulation, with consequent ischemia of a degree sufficient to produce actual gangrene. Rational therapy in such cases is based upon an attempt to counteract vasospasm and to produce maximum vasodilatation in the involved extremity. Since the disturbance is apparently due to a vasomotor reflex initiated in the traumatized tissues, and since vasoconstrictor impulses are transmitted by way of the sympathetic nerve fibers, interruption of these impulses prevents vasospasm and permits vasodilatation. Vasodilatation may be achieved by débridement of surrounding traumatized tissue, by periarterial stripping of the involved area, by procaine hydrochloride block of the regional sympathetic ganglia, or by sympathectomy. Sympathetic block or sympathectomy, which is probably the most effective method of producing maximum vasodilatation in these cases, should be employed in all types of peripheral vascular injuries accompanied by manifestations of vasospasm. It may be necessary to repeat the block at least once or twice daily for several days. Body warmth is carefully main-

tained but heat should not be applied to the involved part. As elevation of the part may accentuate ischemia, the extremity should be maintained at heart level, or preferably in a slightly dependent position.

On a theoretical basis, as well as on the basis of experimental and clinical investigations, the use of anticoagulants (heparin and dicoumarol) would appear to be a valuable adjunct in vascular surgery.[20,21] By this means the extension of thrombosis in the peripheral collateral tributaries or the occurrence of thrombosis after operation at the site of repair, which so often spells failure, can be better controlled. It should be realized, however, that anticoagulant therapy is not without danger, especially in the presence of extensive injury. The method requires careful observation and adequate laboratory checks. Clinically, the exact field of usefulness of anticoagulant therapy in acute vascular injuries has not been defined and must await further experience. That it is not essential to successful repair in certain forms of vascular injury is well known. Perhaps it will be found most useful in cases which require bridging of the arterial gap.

Surgical Therapy. LIGATION. In cases in which ligation is promptly indicated, as in wounds of the smaller noncritical vessels or because of the type and character of the injury, it should be done not by ligation in continuity but by placing nonabsorbable ligatures well above and below the site of injury, with excision of the intervening damaged segment in order to eliminate the dangers of secondary hemorrhage, thrombosis, and vasoconstrictor influences. Although it may be theoretically desirable to ligate at such a level as to avoid the creation of a blind pouch,[10,14] the deliberate effort to do so frequently involves extensive dissection and may still further jeopardize the circulation of the injured limb. If the concomitant vein is also injured, it should be similarly ligated; however, if undamaged it should not be disturbed.

SUTURE REPAIR. As has been indicated, the ideal objective in the therapy of vascular injuries is the restoration of the flow of blood through the original channel. This may be achieved, depending upon the character and extent of the injury, by suture repair, end-to-end anastomosis, or vein grafts and prosthetic tubes. The fundamental principles underlying all of these methods of vascular repair have long been well known. They have remained essentially unchanged, except possibly for certain refinements in suture material or in prosthetic devices, since the time of their establishment through the research efforts of numerous investigators, including, particularly, the work of Glück,[7] Jassinowsky,[12] Murphy,[13] Jaboulay and Briau,[11] Dörfler,[6] Payr,[23] Höpfner,[9] Matas,[15,17] Carrel and Guthrie,[2,3,8] and Moure.[18] The reader will find an excellent historical résumé of this phase of the subject in Matas' publications.[15,17]

Suture repair of arterial injuries is particularly indicated in relatively small longitudinal or oblique wounds or in incomplete transections, especially of the larger arteries, such as the carotid, popliteal, common femoral, subclavian and axillary arteries. In complete or incomplete transections in which there is much loss of substance, end-to-end anastomosis should be

done unless the defect is so great as to preclude approximation and some means of bridging the defect must be employed.

The essential principles of the suture method of vascular repair are: (1) provisional hemostasis; (2) the use of fine needles and silk; (3) accurate approximation of the intima; and (4) gentle handling of tissues. After the injured vessel is exposed and isolated, provisional hemostasis is obtained by applying small rubber-shod spring artery clamps or by clamping soft rubber tubes snugly against the vessel above and below the site of the wound. All traumatized tissue and blood clots are removed, and ragged tissue and overhanging adventitia are excised, to provide clean smooth wound edges. This should be done with considerable care and gentleness to minimize contusion or other injury to the endothelial edges of the wound. The cleansing of the wound and of the lumen of the vessel is facilitated by use of a stream of normal saline solution or of a 1:1,000 solution of heparin in normal saline solution. Periodic irrigation of the structures throughout the operation is also desirable, to prevent drying of the tissues. Traction or guy sutures are placed at each end of the wound, penetrating all layers of the vessels, to facilitate apposition of the endothelial surfaces and the performance of the suture repair (Fig. 479a). The suture material should be of fine silk (00000 or 000000) directly attached to a fine curved needle. This type of atraumatic arterial suture is available commercially in sealed tubes containing liquid petrolatum.

Various methods of applying the suture to approximate the wound edges have been employed, including single interrupted sutures, interrupted mattress sutures, a continuous over-and-over suture (Fig. 479b), or a continuous mattress suture (Fig. 479c). The continuous over-and-over stitch is the simplest and, in general, gives as good results as any of the others. The sutures should be applied fairly close together (about 1 to 1.5 mm. apart), to prevent leakage between them. After the passage of each stitch gentle traction is applied to the thread, so as to approximate the wound edges snugly, care being taken to provide intima-to-intima contact. Following completion of the repair and removal of the hemostatic clamps above and below the artery, slight leakage at the suture line may be observed. Usually it will stop after the application of gentle pressure with moist gauze over the anastomosis. If this is not effective, it can be controlled with a reinforcing suture.

End-to-end Anastomosis. End-to-end anastomosis is indicated in wounds that incompletely or completely transect the vessel unless the loss of substance is so great (more than 2 cm.) that the resultant defect will not permit the ends of the vessel to be brought together without too much tension on the suture line. Under these circumstances, some means of bridging the gap, such as the use of vein grafts or prosthetic tubes, will be necessary. Several methods of end-to-end anastomosis have been employed, including the suture method or the nonsuture method with extra-vasal aids or supporting appliances. The many other methods which have been devised are now only of historical interest.[15,17]

The principles of the suture method of end-to-end anastomosis, which is generally used today, are essentially those developed by Dörfler [6] and perfected by Carrel.[2,3] Following exposure and isolation of the injured vessel, provisional hemostasis is obtained by the application of artery clamps to the artery above and below the site of injury. All traumatized tissue and blood clots are removed and the overhanging adventitia is excised and stripped

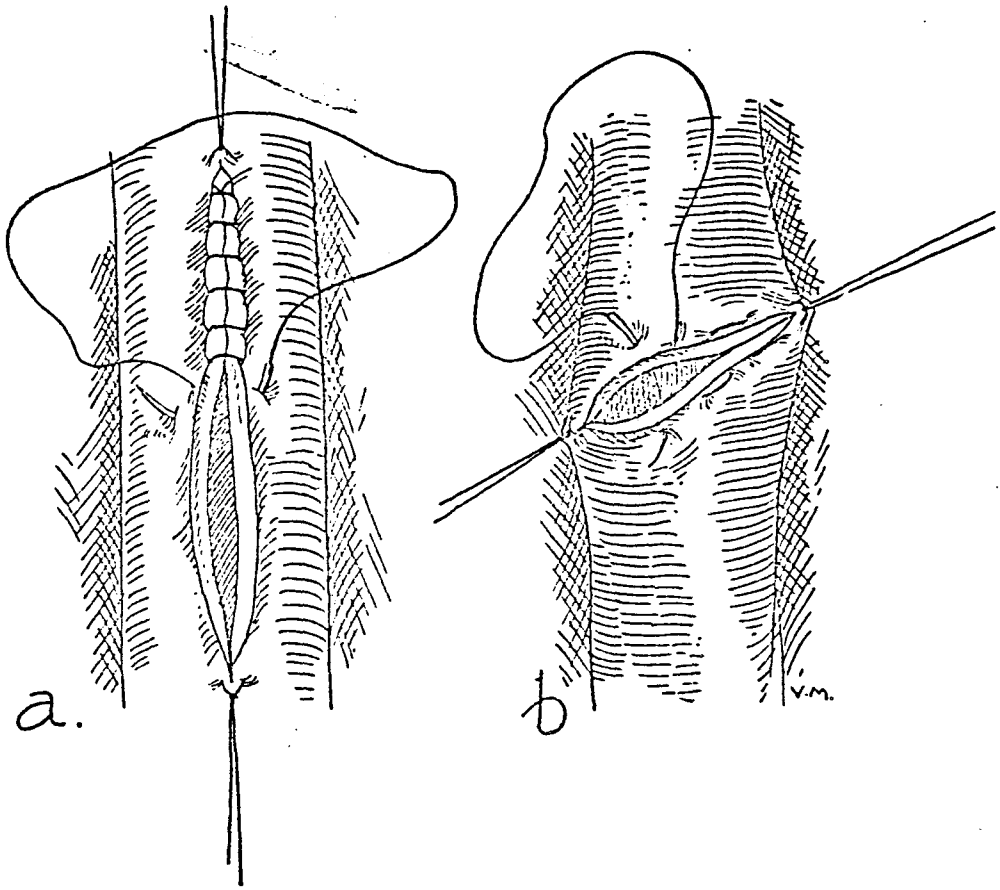

FIG. 479. Technic of suture repair of arterial wounds showing: a, continuous over-and-over type of suture, and b, continuous mattress suture.

away from the edges and the severed ends of the vessel. Irrigation with saline solution or heparin and saline solution is employed, as previously described. The cut ends of the vessel are brought in apposition and three stay sutures are introduced through all layers of the vessel at equidistant points of the circumferences and are tied, care being taken to evert the edges to provide intimal apposition (Fig. 480a). By the application of gentle traction upon these stay sutures the oval outlines of the arterial ends are converted into straight triangular surfaces (Fig. 480b). The new contour facilitates apposition of the surfaces as well as eversion of the edges of the vessel, thus greatly simplifying the performance of suture anastomosis.

Each side of the triangle is sutured consecutively, either by a continuous over-and-over stitch (Fig. 480b and c) or by a continuous mattress suture (Fig. 480d) as described above for lateral arteriorrhaphy, care being taken to provide apposition of the intima. As each segment of the angle is completed, it may be desirable to tie the running suture to the guy stitch.

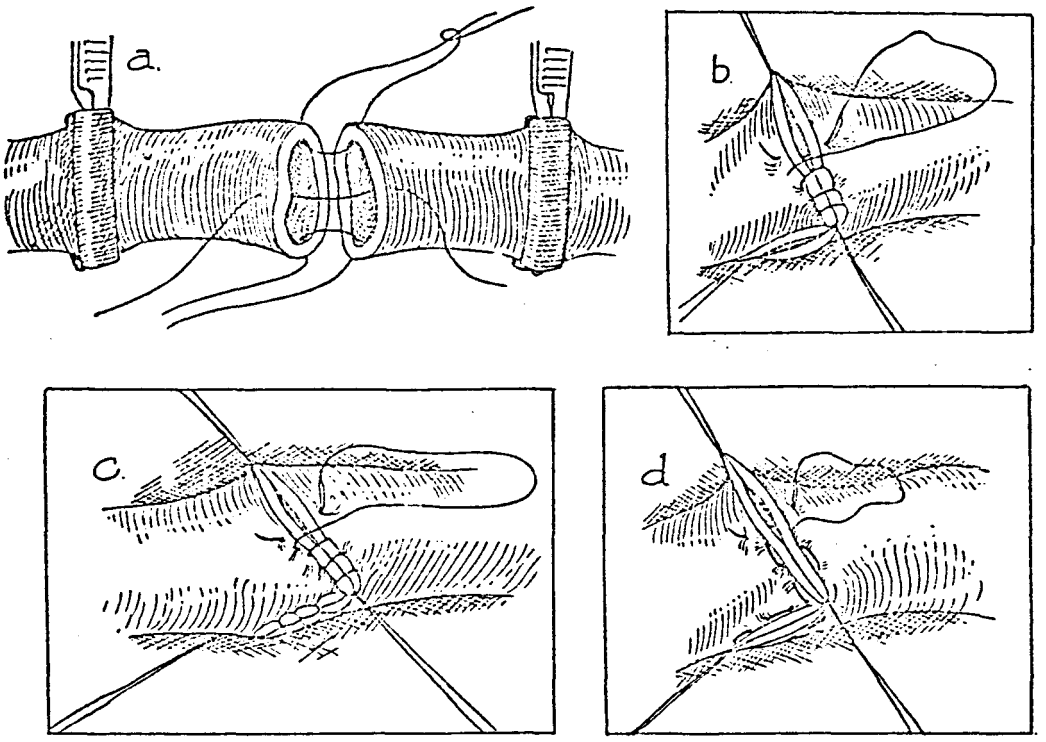

FIG. 480. Technic of end-to-end anastomosis of arteries by suture method showing: a. placement of three stay or guy sutures at equidistant points of the circumference, b. traction upon guy sutures after they have been tied converts oval outline edges of vessels into straight triangular surfaces facilitating suture, c. each side of triangle is sutured consecutively by continuous over-and-over stitch, or d. by continuous mattress suture.

End-to-end anastomosis may also be performed by the nonsuture method, by means of a supporting appliance used to provide intima-to-intima apposition. Of the various types of appliances and technics devised for this purpose the only one that has survived is the method originally developed by Payr in 1900. This method is exactly the same in principle as that recently advocated by Blakemore, Lord, and Stefko,[1] the only difference being that they used vitallium tubes instead of the magnesium alloy tubes employed by Payr. More recently, fibrin tubes have been suggested for this purpose by Swenson and Gross,[3,4] the advantage claimed by these observers being that the tube is gradually absorbed, in a matter of six or seven weeks, and the lumen at the site of the anastomosis is thus able to increase in size with the subsequent growth of the patient. Obviously, this advantage applies particularly to children.

In this method of anastomosis one end of the vessel is threaded through the tube, cuffed back, and fastened with a silk ligature over a groove or a projecting ridge in the tube. The other end of the vessel is then drawn or invaginated over the cuff and secured in position with another ligature. The anastomosis is thus completed and a continuous intimal lining is established (Fig. 481).

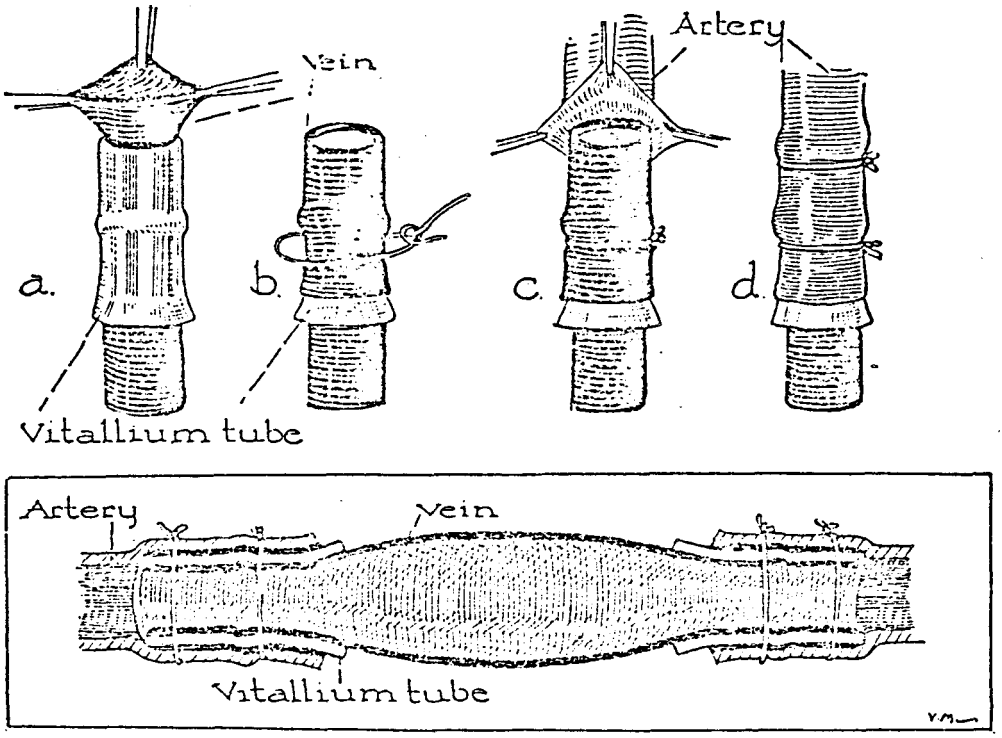

FIG. 481. Technic of end-to-end anastomosis by nonsuture method using vitallium tubes of Blakemore, Lord and Stefko.[1] This drawing shows application of this method of anastomosis for performing vein graft using two tubes but same method may be used for end-to-end anastomosis of arteries using one tube. a. Vein is threaded through tube, b. cuffed back and secured in place with a ligature, c. artery is drawn or invaginated over the cuff, and d. secured in position with two ligatures. The anastomosis thus provides a continuous intimal lining (inset).

The obvious advantages of this method of anastomosis lie in its apparent simplicity and ease of performance. On the other hand, it has certain disadvantages. 1. It utilizes an excess of vessel wall in the performance of the anastomosis and consequently would be impractical in cases in which some loss of substance has already occurred from the original injury. 2. It reduces the caliber of the lumen by the two thicknesses of the vein wall within the tube. In a recent experimental study designed to determine the relative merits of this method of anastomosis and the suture method, the conclusion was reached that in cases in which there is no tension on the suture line and no defect to be bridged, the latter method is superior to the former.[13] Per-

haps the nonsuture method of anastomosis will find its greatest field of usefulness in cases in which it is necessary to bridge the defect in the artery by a vein graft.

In cases in which the injury is associated with such extensive loss of substance as to preclude end-to-end anastomosis and in which arterial ligation does not seem promptly indicated, some method of bridging the gap is desirable in order to restore continuity of the artery. This is particularly true of injuries of critical arteries such as the popliteal, common or internal carotid, common femoral, axillary, and brachial arteries. The various methods suggested and practiced for this purpose include the use of vein grafts and prosthetic tubes.[5] In the vein graft method a suitable segment of vein obtained from an accessible site is anastomosed to the proximal and distal ends of the artery by means of either the suture method or the nonsuture method (Fig. 481). In using vein grafts it is desirable to employ a segment without valves, or, if valves are present, to place the vein between the ends of the artery with the valves facing distally. Another technical consideration is that the vein segment be of the exact length required to bridge the gap, to avoid either tension or kinking.

Bridging of the arterial gap by intubation is another method which has been used to provide for temporary maintenance of the blood flow. Its objective is the maintenance of the circulation of the injured limb until more suitable conditions or facilities permit a permanent type of repair or until the collateral circulation has become established. If this objective can be achieved, an emergency procedure, which may be difficult under the happiest circumstances, is converted into an elective one, or the subsequent gradual obliterative thrombosis in the tube, with occlusion of the main vascular channel, will have a much less deleterious effect than if the process had occurred abruptly. In World War I silver tubes were used for this purpose. In World War II glass tubes as well as plastic tubes were employed.[5,22] Unless circumstances or conditions contraindicate the use of heparin, its administration is particularly desirable with this method of provisional restoration of the vascular continuity, since thrombosis, which will invariably occur, should be delayed as long as possible.

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